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Distribution and Abundance of Atlantic Cod from an Acoustic Survey of Fortune Bay, Newfoundland During the Winter of 1997

by

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Abstract

An acoustic survey was conducted during the winter of 1997 in the coastal waters of Fortune Bay, Newfoundland. The survey area included water depths from the coastline to the 120 m contour. Echo integration along a series of equidistant parallel transects within the survey area provided distributional and behavioral information, densities and a biomass estimate of Atlantic Cod.

Résumé

Un levé acoustique a été effectué dans les eaux côtières de la baie Fortune (Terre-Neuve) au cours de l'hiver 1997. La zone qui a fait l'objet du levé partait de la ligne de côte et allait jusqu'à la ligne de contour de 120 m. Une écho-intégration effectuée le long d'une série de transects parallèles à l'intérieur de la zone du relevé, a fourni de l'information concernant la distribution et le comportement de la morue de l'Atlantique, ainsi que des densités et une estimation de la biomasse.

Introduction

Acoustic surveys have been conducted on an annual basis since the early 1980's as part of the annual research program to assess Atlantic herring stocks in the Newfoundland region. One such survey was conducted during the winter of 1997 in the coastal waters of Fortune Bay (Figure 1). As a result of the use of improved acoustic technology in 1996 (Wheeler and Miller 1997) and again in this survey, it was possible to detect and integrate concentrations of fish in close proximity to the bottom. This paper describes results from this survey and provides distributional and behavioral information, densities and a biomass estimate of Atlantic cod. Caveats to the analyses are also discussed.

Methods

The survey area was defined as the area from the coastline to the 120 m depth contour. The 120 m depth contour was selected as the outer survey boundary as it has been shown that most herring are distributed within this depth range during the survey period (Wheeler et al. 1989). The survey area was divided into strata based upon geographical features and herring distribution patterns. Acoustic sampling intensity (total transect length) was allocated to these strata on a 2:6:11 ratio (for low, medium, and high density strata) based upon herring distribution patterns observed in the commercial fishery and previous acoustic surveys. Within each stratum, the survey design consisted of a series of equidistant parallel transects from the coastline to the 120 m depth contour. To maintain a random design, the placement of the first transect within each stratum was chosen randomly along a reference line drawn parallel to the coastline. Transects were surveyed at a vessel speed of 5.5 to 6.0 knots and transect lengths were measured using the vessel's global positioning system (GPS). Due to the irregular nature of the coastline, transects within strata were of unequal length. Fish densities, integrated on the transects, were weighted to adjust for transect length. A mean weighted density for the stratum was then calculated and extrapolated to the stratum area to estimate fish biomass. Strata estimates were summed to calculate a total biomass estimate for the survey area. The survey design remained unchanged from the last acoustic survey of the area (Wheeler and Winters 1996).

The survey described in this document was conducted from the *R. V. Shamook*; it commenced in Fortune, Fortune Bay on January 10, 1997 and terminated in Bay L'Argent, Fortune Bay on February 5, 1997. The survey was disrupted at various times due to vessel operational delays and bad weather conditions. Although the survey was extended by eight days, three strata had to be eliminated due to insufficient survey time. All of the eliminated strata were in the outer portions of the bay and were considered to be very low probability areas for herring.

In herring acoustic surveys prior to 1996, a *BioSonics* Model 221 echo integrator was used in conjunction with a *BioSonics* Model 105 echo sounder and 120 kHz transducer (operating in single beam mode). In this survey a *Femto* Model 9001 acoustic data acquisition system was used with the same sounder and transducer

configuration. The transducer, mounted in a v-fin, was deployed at a depth of approximately 4 m astern and abeam of the port side of the vessel.

This system was calibrated on October 16, 1996. The calibration parameters were as follows:

Source Level / Receive Sensitivity	42.26 dB
Fixed Receiver Gain:	9.57 dB
TVG Gain:	20 log R
Attenuation Coefficient:	0.03470 dB/m
Pulse Length:	0.4 ms
Average Beam Factor:	-29.4 dB

Where concentrations warranted, and depth and weather conditions permitted, biological samples of cod were collected during the survey using jiggers and feathered hooks. Cod were also sampled as a by-catch in research gillnets set for herring throughout the survey area.

During the survey, a detailed log record was maintained for each transect and also while steaming between transects. Observations were recorded of all fish concentrations (pelagic and groundfish) detected on both the echogram and oscilloscope.

The acoustic data, as recorded in the detailed log, were subsequently edited using the *Femto* acoustic data editing system. Due to the irregular nature of the bottom topography throughout the survey, it was impossible to used a fixed bottom removal algorithm for all transects. Transects on which cod were detected were evaluated on a case by case basis; bottom removal criteria (ie. the size of the exclusion zone above the detected bottom), ranged from 0.5 to 2.0 m depending upon the bottom topography.

Only those fish concentrations considered to be cod were included; pelagic herring concentrations were excluded from the analysis.

Acoustic back-scatter was converted to fish density using the following target strength - fish length relationship calculated for cod by Rose and Porter (1996):

$$T.S. = 20 \log L - 65.5$$

Mean fish lengths were derived from biological samples collected during the survey. Target strength per fish was converted to target strength per unit fish weight using the following cod length - weight relationship (Shelton et. al. 1996):

$$\log W = 3.0879 * \log L - 5.2106$$

Formulas used to calculate mean densities, variances, and biomass estimates remained unchanged from previous surveys and are described in Wheeler (1991).

For the purpose of plotting cod distributions, mean densities (g/m^2) were calculated per 10 sec. (~30 m) intervals along each transect.

Results

During the survey, 148 transects were surveyed from Pass Islands in the west to Grand Jerseyman Head in eastern Fortune Bay (Figure 1). The total length of transects was 120 n.mi. Cod were acoustically detected in all 11 of the strata surveyed and were integrated on 53 (44.2%) transects (Figures 2 and 3). Cod were most prevalent in the Pool's Cove area.

Cod were sampled from 8 different locations throughout the survey area (Table 1 and Figure 3). Sample sizes from each location ranged from 2 - 22 fish. At all sampling locations where jiggers and feathered hooks were used, cod was the only species caught; most cod were caught in close proximity to the bottom (< 2 m). Mean lengths of cod by strata were significantly different (Figure 4). Therefore, although samples sizes were small, it was decided to combine samples, on a stratum basis, to calculate mean lengths required for target strength calculations (Table 2). Length distributions of combined samples by stratum are presented in Figure 5.

During data editing, it quickly became apparent that the size of the exclusion zone above the detected bottom was critical in determining the density and subsequent abundance of cod in close proximity to the bottom. The size of the layer which had to be excluded to ensure that bottom signal was not included as fish, was related to the bottom type and topography. In areas where there was a smooth rocky bottom, the exclusion zone could be kept very small. However, in areas where the bottom was soft (ie. muddy) and provided a weak acoustic signal or in areas where the bottom topography was very rough, the exclusion zone had be kept larger. As was the case for a similar survey conducted in Bonavista Bay - Trinity Bay in 1996 (Wheeler and Miller 1997), it was not possible to determine a standardized bottom removal procedure. Consequently, the bottom removal algorithm was set on a case by case basis for those transects on which cod were detected.

A cod biomass estimate of 2606 t was derived from the survey area (Table 3). Approximately 60% of the estimated biomass was detected in the Pool's Cove stratum (Figure 6). As cod were detected on 8 of 12 transects within this stratum and were also widely distributed throughout the entire survey area, the coefficient of variation based upon survey design (0.320) was relatively low (Table 3).

Due to rapid changes in water depth within strata and near stratum boundaries, not all of the transect coverage was within the defined survey area; 5.0% of the transects occurred in water depths greater than 120 m, to a maximum depth of 196 m (Figure 7). Cod were distributed over a broad range in water depths (9 -137 m), and exhibited a relatively normal distribution with peak densities at a depth of 59 m. Virtually all of the detected cod densities (99.7%) were within the defined survey area (<= 120 m water depth).

As in previous years, the survey was conducted primarily during daylight hours (Figure 8). This was for safety reasons as in surveying the transects, the vessel must navigate very close to shore in restricted areas and depths. During the survey, there was a trend in the time of day when cod were acoustically detected (Figure 8). Approximately 82% of the cod were detected before 1230 h with peak densities between 0815 h and 0845 h.

Discussion

As previously noted in this paper and discussed in Wheeler and Miller (1997), the biomass estimate for bottom dwelling fish such as cod, is very sensitive to the size of the exclusion zone adjacent to the bottom, which must be defined during data editing to ensure that acoustic signals from the bottom are not included as fish. Therefore, the emphasis from this survey should be on distributional and behavioral observations rather than a biomass estimate.

Cod were detected on 44% of the survey transects (Figures 2 and 3). This was very comparable with the 1996 survey of Bonavista Bay - Trinity Bay where cod were detected on 42% of the transects (Wheeler and Winters 1997). In comparison, herring were only detected on 10% of the transects in both of these surveys (Wheeler 1997). This is related to the schooling characteristics of the two species. At the time of the surveys, herring form dense aggregations with a very patchy distribution whereas cod are more loosely aggregated. This observation suggests that the survey timing and design is amenable to both species and can provide valuable quantitative information on their distribution and behavior.

Although cod were detected in all of the surveyed strata, approximately 60% of the estimated biomass was detected in one stratum, in the Pool's Cove area (Figure 6). Cod were detected on 67% of the transects within this stratum compared to 33% in remaining strata (Table 3). This was noticeable during the survey; although cod were detected in all areas, there was a more substantial aggregation in this stratum. Cod were particularly abundant in McGrath's Cove, Turnip Cove and the North Bay areas of the Pool's Cove stratum. Fishers from the area commented that such aggregations in the area were not unusual during the early winter (January - February). There was no obvious reason for the cod to be aggregated in the area; water temperature profiles from the stratum were similar to other strata during the survey, most of the fish sampled within the stratum were immature and were not feeding.

The 120 m depth contour was chosen as the outer boundary of the survey area based upon herring distribution patterns observed in previous acoustic surveys. From the results of this survey, it would also appear to be an appropriate boundary for estimating cod densities at the time of the survey (January - February) as almost all (99.7%) of the cod were detected in water depths less than 120 m (Figure 7). In fact, for this survey, this percentage was greater than for herring, as only 94% of herring were detected within this depth range (Wheeler 1997). There was also no evidence of high

densities of cod in depths greater than 90 m as densities were normally distributed with peak densities at 59 m. These observations were primarily related to the water depths in the Pool's Cove stratum where most of the cod were detected; however, they should be considered when planning future surveys of Fortune Bay.

During the survey, there was a trend in the time of day when cod were acoustically detected (Figure 8). However, caution should be exercised before drawing any conclusions from these results as 60% of the estimated biomass was detected in a single stratum. The temporal results may only be an indication of the time of day that this stratum was surveyed.

Important distributional and behavioral observations of cod have been derived from this survey. The biomass estimate should be considered a minimum given the previously discussed constraints regarding the size of the bottom exclusion zone. Further research is required on the effects of the size of this zone before attempting to estimate the abundance of cod acoustically in broad-scaled surveys of coastal Newfoundland waters.

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Finally, but not least, I would like to thank Pelagic Section personnel who contributed to the success of the survey.

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Table 1. Biological sampling details of cod, Shamook Trip #262, Fortune Bay, January - February, 1997.

Stratum	Sample Date	Sample Location	Gear Type	Sample #	n	Mean Lgt. (cm)
6	Jan. 19	Chapel Island, Belleoram	Res. Gillnet	RGN3	2	54.5
	Jan. 24	Iron Head, Belleoram	Res. Jiggers	RJ7	17	57.5
7	Jan. 24	Cinq Island Head, Belle Bay	Res. Jiggers	RJ8	15	49.4
	Jan. 24	McGrath Cove, Belle Bay	Res. Jiggers	RJ10	22	49.1
	Jan. 25	North Bay, Belle Bay	Res. Jiggers	RJ11	20	49.7
9	Jan. 27	Gull Rocks, Long Harbour	Res. Jiggers	RJ13	20	55.7
	Jan. 28	Tickle Beach, Long Harbour	Res. Gillnets	RGN12	8	63.9
11	Jan. 21	East Bay	Res. Gillnets	RGN5	2	44.5

Table 2. Mean cod lengths and weights, by stratum, used to calculate target streng for 1997 Fortune Bay acoustic survey.

Stratum	Combined Samples	Mean Lgt. (cm)	Mean Wgt. (kg)	TS / fish (dB)	TS (dB /g)
6	RGN3, RJ7	57.2	1.64	-30.35	-62.50
7	RJ8, RJ10, RJ11	49.4	1.05	-31.63	-61.84
9	RGN12, RJ13	58	1.72	-30.23	-62.59
11	RGN5	44.5	0.76	-32.53	-61.34

Table 3. Fortune Bay cod biomass estimate from 1997 acoustic survey.

STRATUM	STRATUM AREA (sq. m.)	TRANS. NO.	TRANS. LGT. (n.mi.)	TRANS. AREA (sq. m.)	DENSITY (g/sq.m.)	WEIGHTED DENSITY (g/sq.m.)	STRATUM BIOMASS (t)
1	1.972E+08	13	0.32	592.6	0.0000	0.0000	
		14	0.54	1000.1	2.0097	0.7544	
		15	1.92	3555.8	0.0226	0.0302	
		16	2.22	4111.4	3.9709	6.1279	
		109	0.34	629.7	0.0000	0.0000	
		110	2.74	5074.5	0.0000	0.0000	
		111	1.99	3685.5	0.0000	0.0000	
		7		2664.2		0.9875	195
2	7.170E+07	1	0.13	240.8	0.0000	0.0000	
		2	0.78	1444.6	0.0000	0.0000	
		3	0.36	666.7	0.0000	0.0000	
		4	0.32	592.6	0.0000	0.0000	
		5	0.22	407.4	0.0000	0.0000	
		6	0.47	870.4	0.0000	0.0000	
		7	0.13	240.8	0.6530	0.1353	
		8	0.58	1074.2	0.0000	0.0000	
		9	0.49	907.5	0.0000	0.0000	
		10	0.35	648.2	0.0000	0.0000	
		11	0.99	1833.5	0.0000	0.0000	
		12	0.97	1796.4	0.0000	0.0000	
		113	0.79	1463.1	0.0000	0.0000	
		114	0.77	1426.0	0.0000	0.0000	
		115	1.02	1889.0	0.0000	0.0000	
		116	1.28	2370.6	0.1303	0.2667	
		117	1.02	1889.0	0.0000	0.0000	
		17		1162.4		0.0236	2
3	7.260E+07	118	2.46	4555.9	2.0650	3.4847	
		119	0.47	870.4	5.6167	1.8109	
		126	0.98	1815.0	0.0849	0.0571	
		125	1.27	2352.0	0.0000	0.0000	
		124	1.91	3537.3	2.5301	3.3150	
		123	2.00	3704.0	0.0000	0.0000	
		122	2.26	4185.5	0.0000	0.0000	
		121	0.68	1259.4	0.0000	0.0000	
		120	1.09	2018.7	0.0000	0.0000	
		9		2699.8		0.9631	70
5	9.240E+07	23	0.59	1092.7	0.0000	0.0000	
		22	1.90	3518.8	0.0374	0.0597	
		21	1.32	2444.6	0.0000	0.0000	
		20	1.67	3092.8	0.0000	0.0000	
		19	0.90	1666.8	0.0000	0.0000	

Table 3 (cont.'). Fortune Bay cod biomass estimate from 1997 acoustic survey.

STRATUM	STRATUM AREA (sq. m.)	TRANS. NO.	TRANS. LGT. (n.mi.)	TRANS. AREA (sq. m.)	DENSITY (g/sq.m.)	WEIGHTED DENSITY (g/sq.m.)	STRATUM BIOMASS (t)
5 (cont.')		18	0.76	1407.5	0.0000	0.0000	
		6		2203.9		0.0100	1
6	9.080E+07	40	0.04	74.1	0.0000	0.0000	
		39	0.04	74.1	0.0000	0.0000	
		38	0.58	1074.2	39.7061	16.4758	
		37	1.86	3444.7	0.0000	0.0000	
		36	1.21	2240.9	41.5892	36.0021	
		34	1.74	3222.5	1.0046	1.2506	
		35	0.51	944.5	0.7431	0.2711	
		33	1.41	2611.3	9.2455	9.3263	
		32	1.25	2315.0	0.7381	0.6601	
		31	1.17	2166.8	0.0000	0.0000	
		30	1.42	2629.8	9.4710	9.6216	
		29	2.45	4537.4	0.3580	0.6275	
		17	2.88	5333.8	0.7085	1.4598	
		28	2.18	4037.4	0.0000	0.0000	
		27	2.11	3907.7	0.7630	1.1518	
		26	1.84	3407.7	0.3582	0.4715	
		25	1.40	2592.8	10.6857	10.7027	
		24	1.07	1981.6	8.2421	6.3093	
		18		2588.7		5.2406	476
7	3.390E+07	44	0.86	1592.7	0.1835	0.2015	
		45	1.00	1852.0	0.3277	0.4183	
		43	0.91	1685.3	0.5672	0.6589	
		42	1.21	2240.9	0.0000	0.0000	
		41	0.56	1037.1	0.0000	0.0000	
		46	0.50	926.0	0.0000	0.0000	
		47	0.07	129.6	51.5817	4.6094	
		48	0.28	518.6	5.5891	1.9978	
		49	1.40	2592.8	111.2548	198.8384	
		50	2.17	4018.8	118.0719	327.0843	
		51	0.23	426.0	0.0000	0.0000	
		52	0.21	388.9	67.1809	18.0102	
		12		1450.7		45.9849	1559
8	4.660E+07	136	1.39	2574.3	4.0412	10.0635	
		135	0.16	296.3	0.0000	0.0000	
		134	0.26	481.5	0.0000	0.0000	
		133	0.42	777.8	2.0617	1.5513	
		132	0.24	444.5	0.0000	0.0000	
		131	0.18	333.4	1.0325	0.3330	
		130	0.77	1426.0	0.0000	0.0000	
		129	0.39	722.3	0.0000	0.0000	

Table 3 (cont.'). Fortune Bay cod biomass estimate from 1997 acoustic survey.

STRATUM	STRATUM AREA (sq. m.)	TRANS. NO.	TRANS. LGT. (n.mi.)	TRANS. AREA (sq. m.)	DENSITY (g/sq.m.)	WEIGHTED DENSITY (g/sq.m.)	STRATUM BIOMASS (t)
8 (cont.')		127	0.50	926.0	0.0000	0.0000	
		128	1.02	1889.0	3.0125	5.5049	
		137	1.11	2055.7	0.0000	0.0000	
		138	0.59	1092.7	22.6782	23.9709	
		139	0.48	889.0	0.0000	0.0000	
		140	0.11	203.7	0.0000	0.0000	
		141	0.60	1111.2	0.0000	0.0000	
		142	0.13	240.8	0.0000	0.0000	
		143	0.11	203.7	0.0000	0.0000	
		144	0.88	1629.8	1.5848	2.4985	
		145	0.22	407.4	0.0000	0.0000	
		146	0.59	1092.7	0.0000	0.0000	
		147	0.55	1018.6	0.0000	0.0000	
		148	1.58	2926.2	0.0000	0.0000	
		22		1033.8		1.9965	93
9	2.920E+07	62	0.19	351.9	0.0000	0.0000	
		63	0.34	629.7	0.0000	0.0000	
		64	0.16	296.3	0.0000	0.0000	
		65	0.07	129.6	0.0000	0.0000	
		66	0.52	963.0	53.1151	41.2237	
		67	0.63	1166.8	0.0000	0.0000	
		68	0.60	1111.2	0.0000	0.0000	
		69	0.49	907.5	0.0000	0.0000	
		70	0.53	981.6	0.0000	0.0000	
		71	0.80	1481.6	0.4543	0.5424	
		72	0.21	388.9	0.0000	0.0000	
		73	1.67	3092.8	0.2155	0.5371	
		78	1.62	3000.2	0.0000	0.0000	
		77	1.39	2574.3	0.0000	0.0000	
		76	1.30	2407.6	2.9436	5.7115	
		75	0.73	1352.0	0.7745	0.8439	
		74	0.14	259.3	0.0000	0.0000	
		17		1240.8		2.8740	84
10	2.840E+07	95	0.27	500.0	0.0000	0.0000	
		96	0.08	148.2	0.0000	0.0000	
		97	0.04	74.1	0.0000	0.0000	
		98	0.21	388.9	0.0000	0.0000	
		99	0.35	648.2	0.0000	0.0000	
		100	0.26	481.5	0.0000	0.0000	
		101	0.28	518.6	16.0458	12.8892	
		102	0.70	1296.4	0.0000	0.0000	
		103	0.26	481.5	0.0284	0.0212	
		104	0.27	500.0	0.0000	0.0000	
		105	0.33	611.2	0.0000	0.0000	
		106	0.56	1037.1	0.0000	0.0000	

Table 3 (cont.'). Fortune Bay cod biomass estimate from 1997 acoustic survey.

STRATUM	STRATUM AREA (sq. m.)	TRANS. NO.	TRANS. LGT. (n.mi.)	TRANS. AREA (sq. m.)	DENSITY (g/sq.m.)	WEIGHTED DENSITY (g/sq.m.)	STRATUM BIOMASS (t)
10 (cont.')		107	0.78	1444.6	0.0000	0.0000	
		108	0.49	907.5	1.1078	1.5573	
		14		645.6		1.0334	29
11	4.180E+07	79	0.45	833.4	0.0000	0.0000	
		80	0.54	1000.1	0.0000	0.0000	
		82	0.19	351.9	0.0000	0.0000	
		81	2.77	5130.0	0.0000	0.0000	
		85	2.40	4444.8	0.2973	1.0873	
		84	1.03	1907.6	0.0228	0.0358	
		83	1.29	2389.1	16.1497	31.7457	
		86	0.17	314.8	0.5231	0.1355	
		87	0.13	240.8	0.0000	0.0000	
		88	0.10	185.2	0.0000	0.0000	
		89	0.17	314.8	0.0000	0.0000	
		90	0.07	129.6	0.5585	0.0596	
		91	0.16	296.3	0.0000	0.0000	
		92	0.34	629.7	0.1062	0.0550	
		93	0.32	592.6	0.0000	0.0000	
		94	0.37	685.2	0.7130	0.4020	
		16		1215.4		2.0951	88
12	5.680E+07	61	0.74	1370.5	0.0000	0.0000	
		60	1.22	2259.4	0.0000	0.0000	
		59	1.15	2129.8	0.0000	0.0000	
		58	0.94	1740.9	0.0000	0.0000	
		57	0.94	1740.9	0.0000	0.0000	
		56	0.34	629.7	3.9903	1.6259	
		55	0.69	1277.9	0.0000	0.0000	
		54	0.79	1463.1	0.0000	0.0000	
		53	0.70	1296.4	0.0000	0.0000	
		9		1545.4		0.1807	10

Total Transect Length 122.12

Total Estimated Biomass = 2606

S.E. = 833

C.V. = 0.320

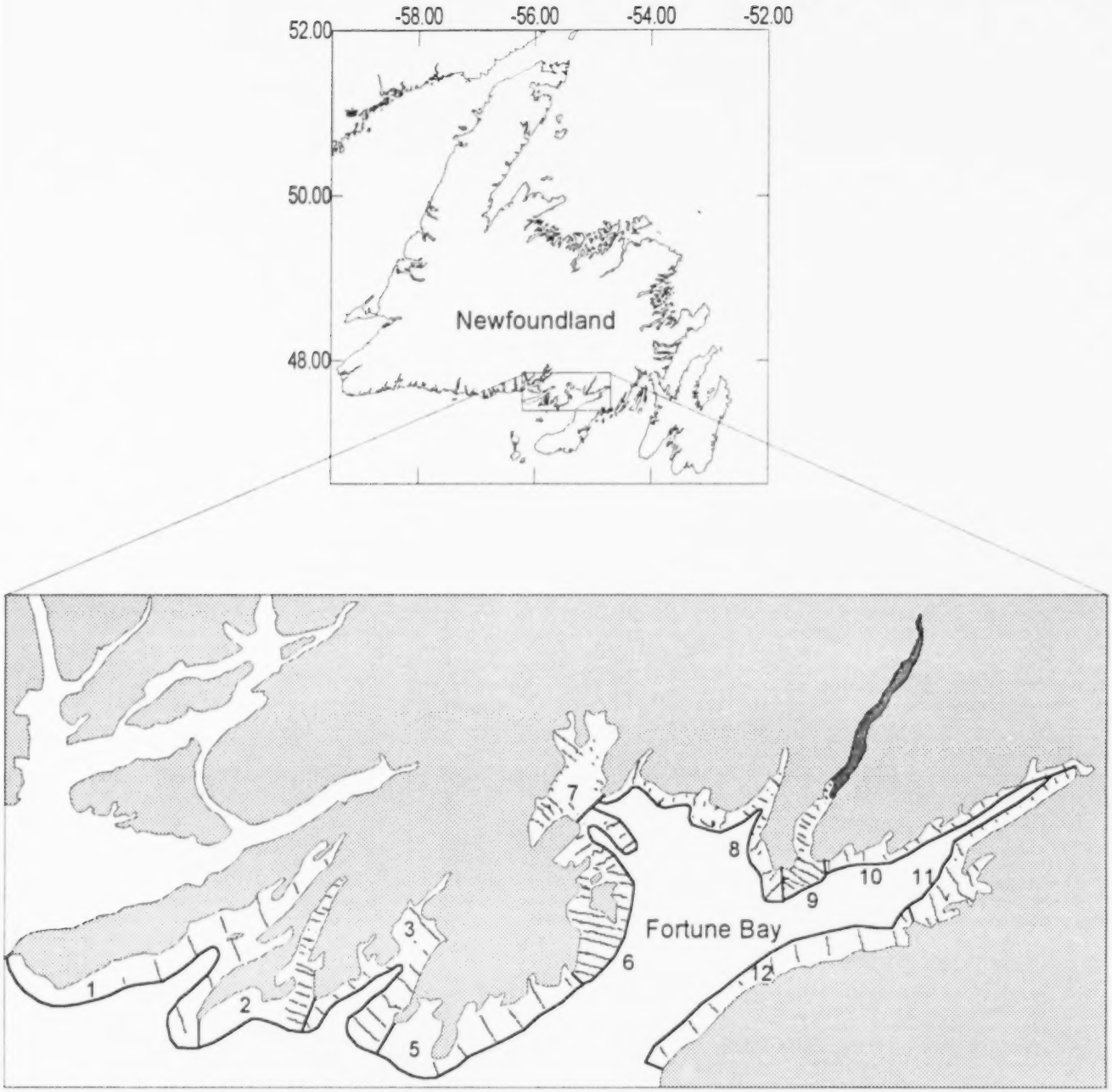

Fig. 1. Area map of Fortune Bay indicating survey strata and transects for the 1997 winter acoustic survey. Strata boundaries include water depths <= 120 m.

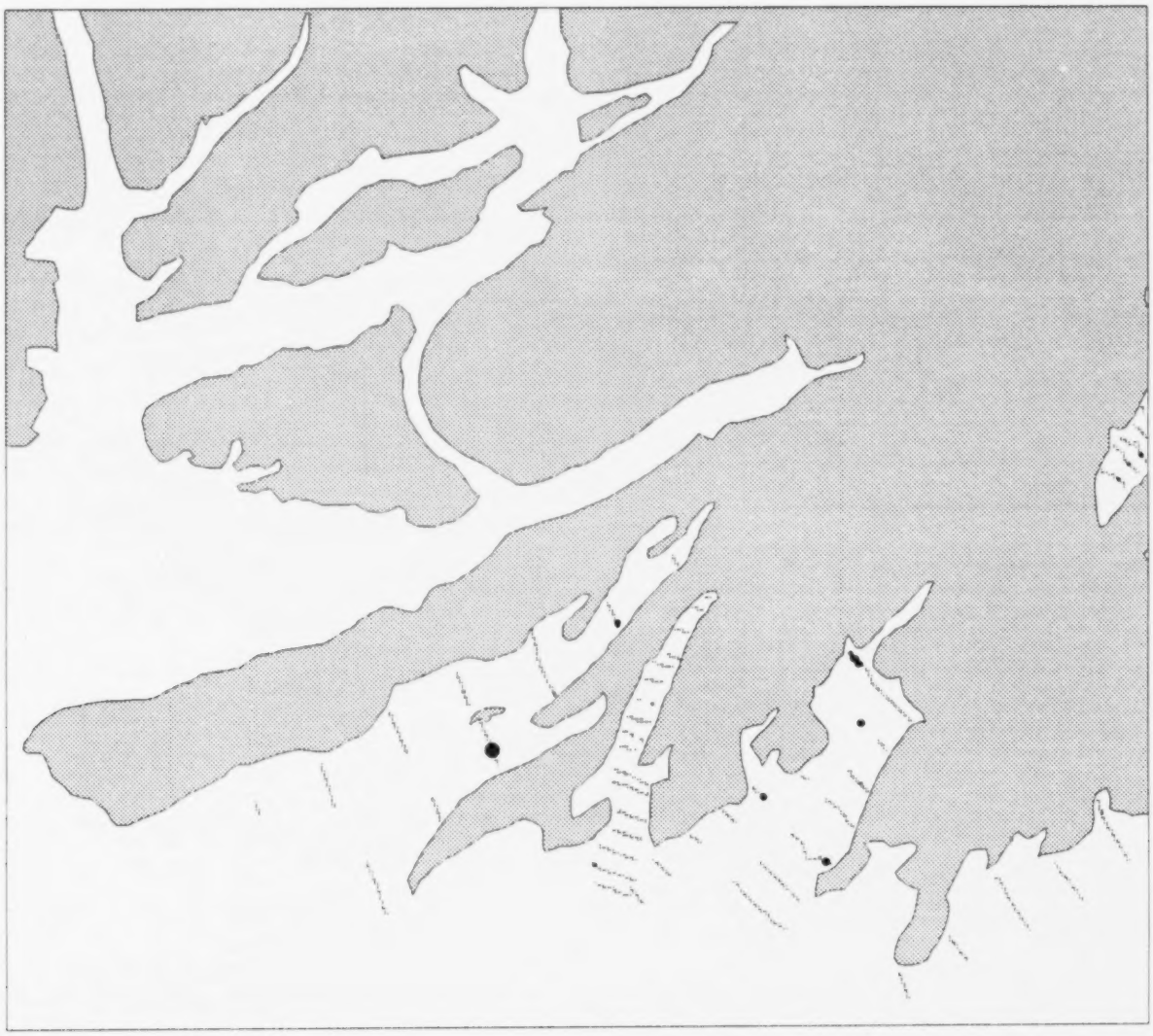

Fig. 2. Distribution and density of cod on transects in western Fortune Bay during the 1997 acoustic survey.

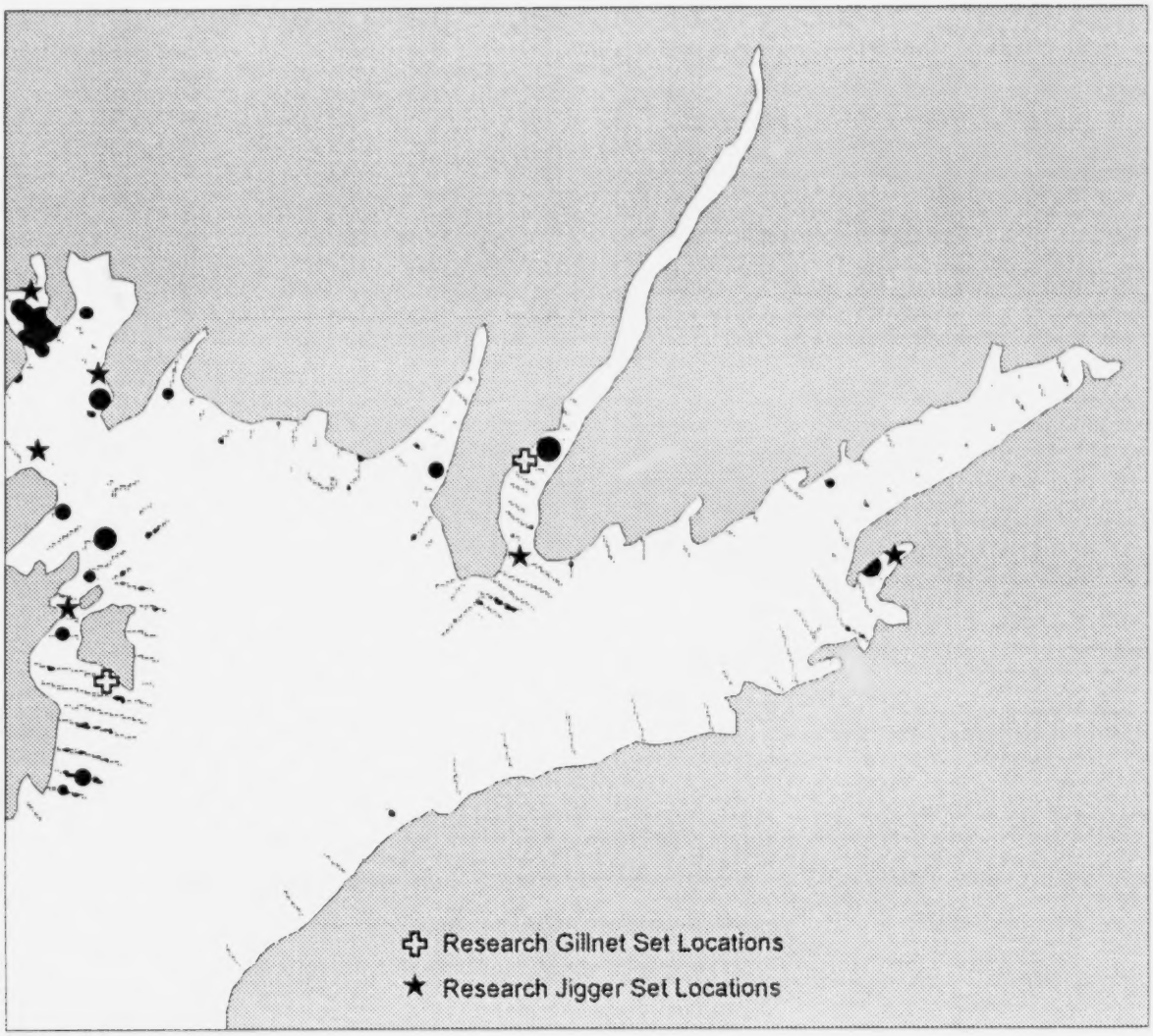

Fig. 3. Distribution and density of cod on transects in eastern Fortune Bay during the 1997 acoustic survey.

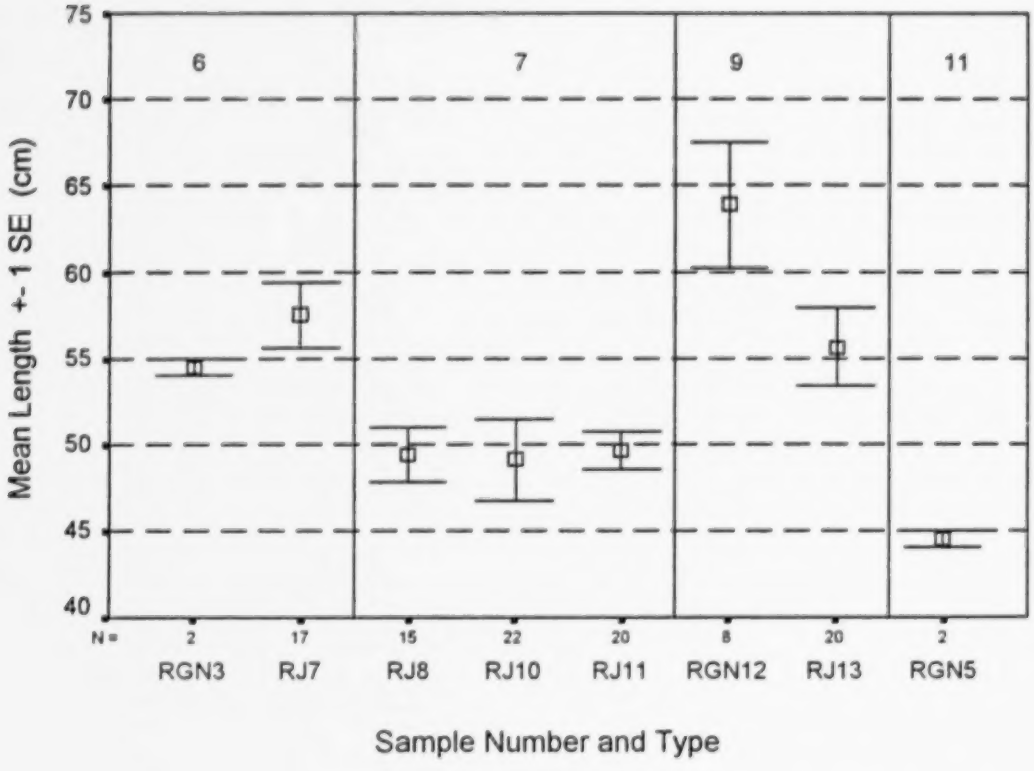

Fig. 4. Mean cod lengths (cm) by sample number, sample type, and stratum, from 1997 Fortune Bay acoustic survey.

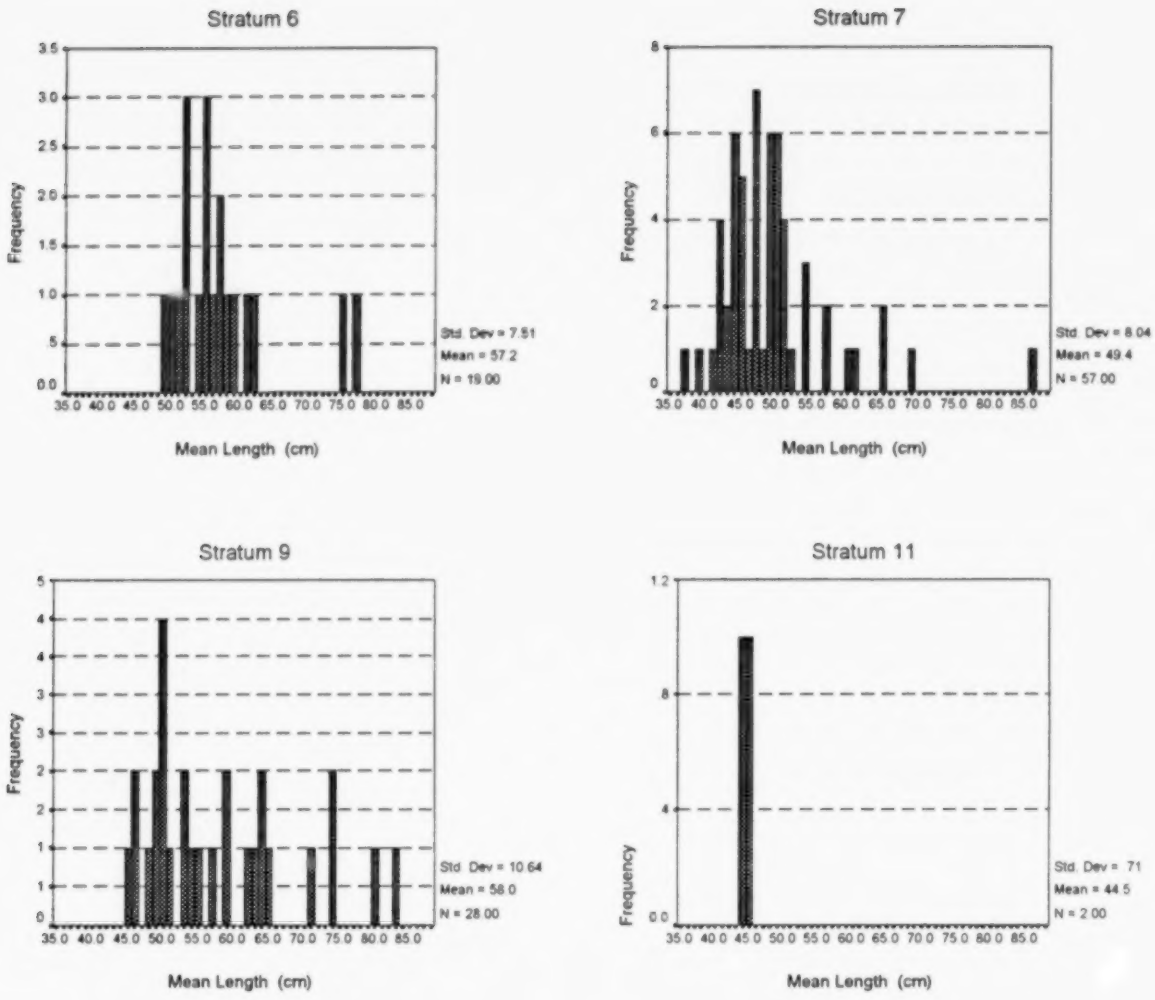

Fig. 5. Length distributions of cod samples, by stratum, from 1997 Fortune Bay acoustic survey.

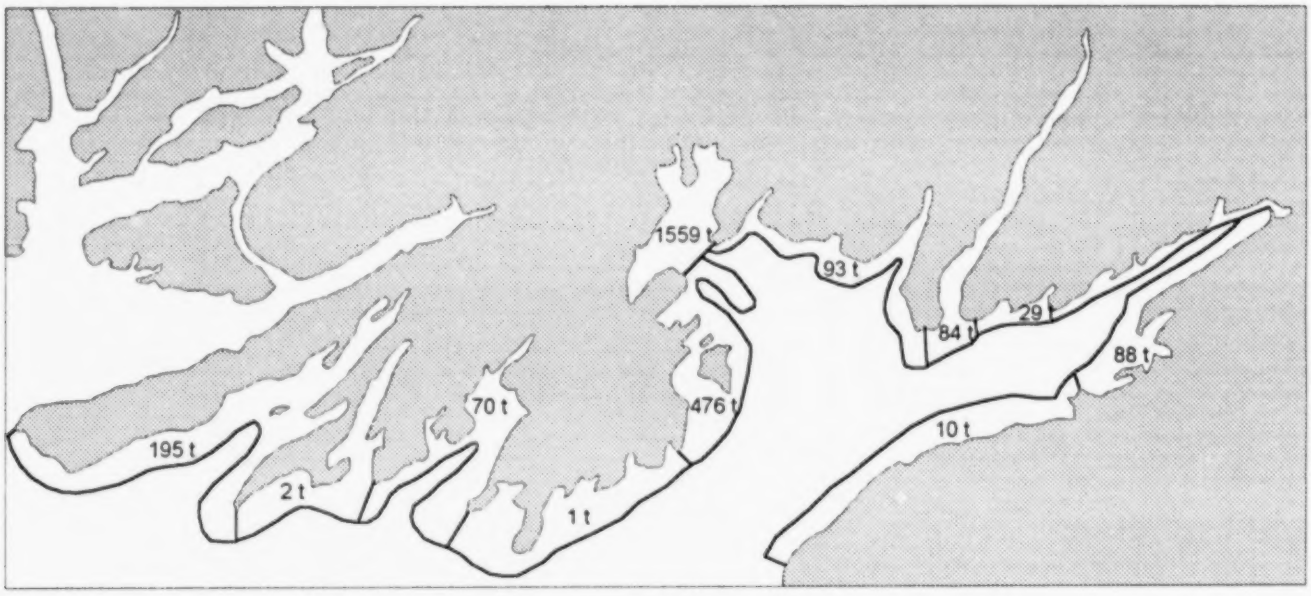

Fig. 6. Cod biomass estimates by survey strata for Fortune Bay from the 1997 acoustic survey.

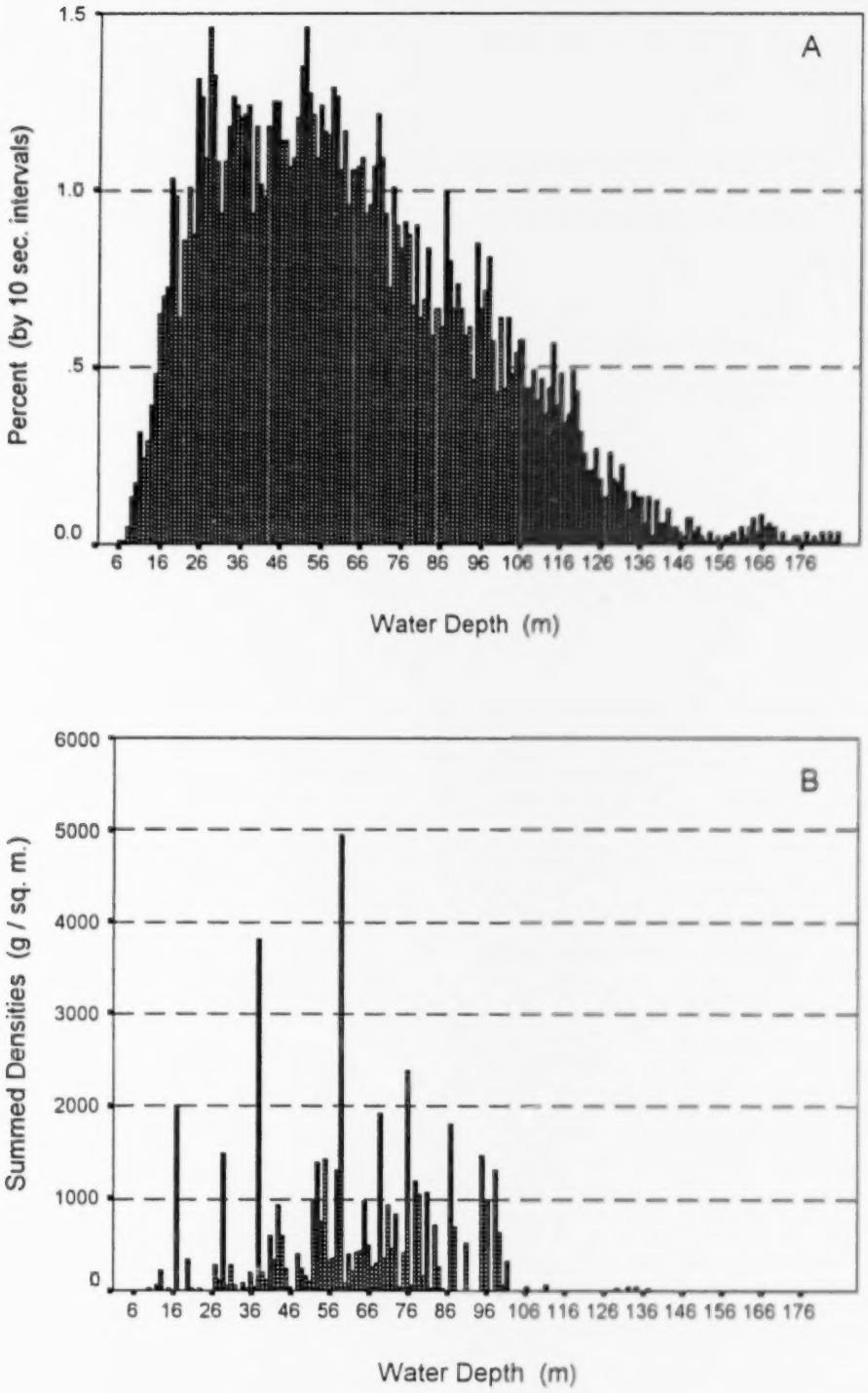

Fig. 7. Distribution of acoustic sampling by water depth (Panel A) and summed densities of cod by water depth (Panel B) from the 1997 Fortune Bay acoustic survey.

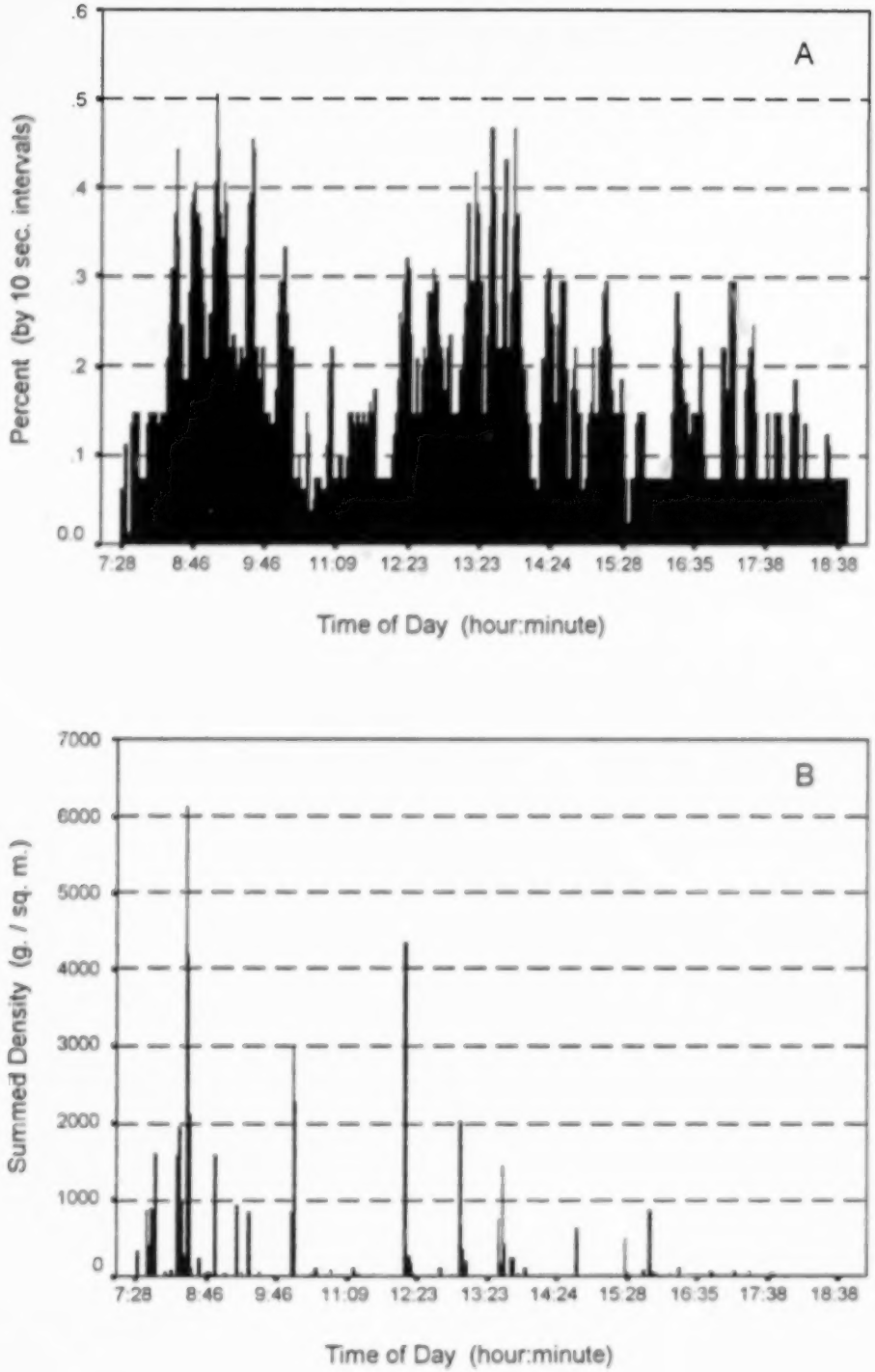

Fig. 8. Distribution of acoustic sampling by time of day (Panel A) and summed densities of cod by time of day (Panel B) from the 1997 Fortune Bay acoustic survey.